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Disease index for basal stem rot of arecanut in North East India

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Basal stem rot caused by the fungus, *Ganoderma* sp. is the most important disease of arecanut in the north east region of India. The characteristic symptoms of the disease are drooping of older leaves, yellowing of leaves, tapering of stem, reduction in leaf size, oozing from the base of the palm up to a height of 1 m, rotting of roots and development of fruiting bodies (sporophore) which later turns to chocolate colour with age. The lower surface of the fruiting bodies is white colour in the initial stage. Numerous spores are found on the fruiting bodies which act as a means for secondary spread of the disease through air. However, the development of fruiting bodies and oozing from the base of the stem are found to be erratic in ganoderma affected arecanut palms. Until now, no satisfactory techniques have been developed to detect early infection of the disease, although Reddy and Ananthanarayanan (1984) reported that fluorescence antibody technique is available to detect *G. lucidum* in roots of arecanut.

Development of index for a specific disease will help in identification of disease severity and the application of correct management measures. In coconut, indexing for assessing the severity of the disease was reported by Bhaskaran and Karthikeyan (1994). Exact diagnosis of *Ganoderma* infection in arecanut is based on the appearance of sporophores and oozing at base of the palm, although they are observed only when the disease is fully established. Sub-clinical infections thus remain undetectable, and mycelial state in the soil and surrounding plant debris cannot be detected and identified. In this paper, the authors developed an index keeping in view the external symptoms that appears in the disease affected palm in NE region of India.

The study was carried out at Central Plantation Crops Research Institute (CPCRI), Research Centre, Kahikuchi campus as well as in the farmers' fields. Survey was concentrated in 39, 8, 12, 5 and 7 villages of Kamrup, Goalpara, Darrang, Nagaon and Morigaon districts respectively. The region under study receives an annual rainfall of 2500-3000 mm, of which 85 per cent is received during monsoon period from June 15 to August 15. The mean monthly maximum temperature ranged between 20 to 36 ^{o}C and the mean monthly minimum temperature ranged between 8 to 22 ^{o}C. The relative humidity varies between 67-97 per cent.

Observations were recorded for 558 *Ganoderma* affected arecanut palms in the age group of 15-30 years on seven parameters *viz.*, (i) number of functional leaves, (ii) number of drooping non-functional leaves, (iii) number of yellow non-functional leaves, (iv) tapering of stem, (v) reduction in leaf size, (vi) presence of fruiting bodies and (vii) presence of oozing. A visual score of 0-4 was given for tapering of stem and reduction in leaf size which usually occur beyond the middle stage of the disease. Grade '0' was given when there was no reduction in leaf size and 4 when there was 50 per cent or more reduction in leaf size by visual observation compared to healthy palm in the same garden. Similarly, a '0' grade was marked for no tapering and depending upon the severity of the tapering 1-4 grades was given. A visual score of 4 was given to those palms where the girth of the trunk apex was almost half that of the girth at one meter

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height and girths in between them were given score of 1-3. The presence of fruiting bodies and oozing was noted against each palm and a score of 0 or 1 was assigned depending upon the presence or absence of fruiting bodies/oozing in the affected arecanut palm.

To develop the disease index, a two stage approach was followed. The disease affected palms were classified into disease severity classes by following two step clustering method. This method of clustering has the advantage of providing optimum number of clusters based on both continuous and categorical variables. The clusters thus obtained were then used to represent the disease severity in an ordinal scale and regressed with observed variable to obtain the disease index. Once the regression estimates are obtained the index formula was derived as

$$\text{Disease index} = \frac{(\text{Disease score} - \text{Minimum score})}{(\text{Maximumscore} - \text{Minimum score})} \times 100 \quad (1)$$

Table 1. Summary of Chi-square tests describing the association of categorical variables with number of drooping leaves

Variables	Chi-square value	p-value
Tapering of stem	199.75 *	<.0001
Reduction in leaf size	427.68 *	<.0001
Presence/absence of fruiting bodies	12.65 *	<.0001

*denotes significance at 1% level

SPSS v.16.0 was used for carrying out the statistical analysis.

Survey carried out in different districts of Assam revealed that the per cent incidence were 0.1 to 26 per cent in Kamrup, 33 to 65 per cent in Goalpara, 0.1 to 6 per cent in Darrang, 3 to 4 per cent in Nagaon and 0.5 to 1.per cent in Morigaon. Mortality was as high as 90 per cent in the above infested gardens (CPCRI, 2012). The devastation was also coupled with poor management of garden and lack of awareness among the farmers about the disease.

A strong negative correlation coefficient (-0.823**) between the variables, number of drooping leaves and number of functional leaves, was observed. Table 1 depicts the summary of chi-square tests for independence among the categorical variables such as status of tapering of stem, reduction in leaf size and presence/absence of fruiting bodies. The tests revealed that there exists a strong evidence of association among them. Further analysis revealed that the variables, tapering of stem and reduction in leaf size, were positively associated. The presence/absence of fruiting bodies was also positively associated with number of drooping leaves as well as the number of functional leaves.

The two step cluster analysis resulted in four clusters: The centroids of the clusters obtained are shown in Table 3.

Table 2. Summary of phi-coefficients among the categorical variables as well as numeric variables to measure the associations

Variable	No. of drooping leaves	No. of functional leaves	Tapering of stem	Reduction in leaf size
Tapering of stem	0.342*	0.427*	-	-
Reduction in leaf size	0.453*	0.497*	0.774*	-
Presence/absence of fruiting bodies	0.657*	0.704*	0.203*	0.262*

* denotes significance at 1% level

Table 3. Mean and frequencies of considered variables across the four clusters formed by following two step procedures

Cluster	Average number of drooping leaves	Frequency of categorical variables								
		Tapering of stem			Reduction in leaf size				Fruiting body	
		0	1	2	0	1	2	3	0	1
1	0.33	195	0	0	195	0	0	0	195	0
2	0.46	0	98	0	28	48	19	3	98	0
3	0.78	94	0	0	94	0	0	0	0	94
4	0.78	24	105	42	13	105	53	0	28	143

Table 4. Estimates of regression coefficients using regression

Parameter	Coefficient
(Constant)	1.136 **
Dl to tl ratio#	0.145 *
Fruiting body	1.705 **
Tapering of stem	0.572 **
Reduction in leaf size	0.350 **

**, * denote the significant at 1% & 5% level of significance, respectively; # denotes ratio of drooping leaves to total number of leaves

The estimates of regression coefficients on fitting the disease severity score with the four regressor variables are shown in Table 4. All the variables included in the regression were found to have significant coefficients.

The formula can be depicted as:

Disease score = 1.136 + (1.705 x fruiting body) + (0.572 x tapering of stem) + (0.145 x dl to tl ratio) + (0.350 x reduction in leaf size).

Calculation of indexing formula

The disease index was considered as the model comprising ratio of number of drooping leaves to total number of leaves, scores given for tapering of stem, reduction in leaf size and presence or absence of fruiting bodies in the palm.

The correlations revealed that there was significant negative correlation between number of drooping leaves and number of functional leaves. The measures of association using phi- coefficient among the categorical variables as well as numeric variables explained that tapering of stem and reduction in leaf size, were positively associated and presence/absence of fruiting bodies had a strong positive association with number of drooping leaves as well as the number of functional leaves.

The indexing for ganoderma was carried out in the scale of 0-100 in which '0' represents no disease and '100' severe disease. Ratio of drooping leaves to total number of leaves was computed in order to represent the importance of proportion of drooping leaves than the number of leaves. Developed regression model gives the minimum score as 1.136 (when all the independent variables take the value zero) and highest score as 6.674 (where each variable takes corresponding maximum values). Accordingly, the disease index was computed accordingly as: (disease score -1.136)/ (6.674-1.136) x 100.

Thus final indexing can be expressed as:

Disease Index (DI) = {(1.705 x fruiting body) + (0.572 x tapering of stem) + (0.145 x dl to tl ratio) + (0.350 x reduction in leaf size)} x 18.057.

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